Requirements Criteria for Applicable Environmental Scanning Systems: Model Development and First Demonstration

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Abstract

Especially in turbulent times, environmental scanning systems are an important instrument for supporting managerial decision making. The 2008/2009 economic crisis provided a sustainable impulse for focusing earlier on emerging threats and opportunities. Although a rich body of knowledge exists, concepts remain unused in practice. Most often they lack applicability. This article provides a list of requirements criteria specifying the applicability of environmental scanning systems. It is based on the principle of economic efficiency, uses findings from the absorptive capacity theory and can be applied to both evaluate existing environmental scanning systems and develop a new, more applicable generation than those we researched. We end with evaluating an environmental scanning system of a large, international company.

1 Introduction

With an increasing volatility executives worry about not being prepared for environmental shifts or not being able to parry them. The 2008/2009 economic crisis provided a sustainable impulse for focusing earlier on emerging threats and opportunities [16] – and the volatile environment in summer 2011 has ensured that this topic stays relevant. Environmental scanning – ideally, information systems (IS)-based – can help to manage this challenge. Companies that do so will have brighter prospects than those that do not [3].

With Ansoff's [3] article “Managing Strategic Surprise by Response to Weak Signals” as an example, a rich body of knowledge exists, but practitioners experience *difficulties* in designing, implementing, and operating environmental scanning systems. Thus, these concepts remain *unused* in practice and the question of an applicable design remains not answered in both research and practice. To give more applicable environmental scanning systems design a starting point, a new examination of requirements that specify applicability should be helpful. Thus the objective of this article is to provide a list of requirements criteria for environmental scanning systems using a systematic approach.

Our article contributes to better environmental scanning system design by systematically developing a *list specifying requirements criteria to improve environmental scanning system's applicability*. Based on the principle of economic efficiency and using findings from the absorptive capacity theory, such a list of requirements can be applied to both evaluate existing environmental scanning systems and develop a new, more applicable generation of environmental scanning systems.

We adhere to design science research (DSR) in IS focusing on developing innovative, generic solutions for practical problems and thus emphasize utility [15]. According to Hevner et al. [15] and March and Smith [22] the outcomes of a construction process are constructs, models, methods, and instantiations. The requirements list to be developed can be categorized as a *model*. It aims at balancing the needs of practitioners and those of researchers by developing applicable requirements without sacrificing scientific rigor.

Structuring this article, we follow Peffers et al.'s six step approach [29]. After the problem statement, Sec. 2 gives an overview of environmental scanning systems and their requirements. In Sec. 3 we present a state-of-the-art review and develop an approach for rigorously collecting requirements criteria. Sec. 4 then demonstrates a first instantiation in terms of the list of requirements. Sec. 5 proceeds with a demonstration in a large, international company. Finally, we evaluate our model in Sec. 6 and conclude the article with an outlook and a proposal for further research in Sec. 7.

2 Foundations

A company's environment could be defined as the relevant physical and social factors within and beyond the organization's boundaries [9]. While operational analysis focuses on (short-term) internal difficulties in the implementation of strategic programs, strategic environmental scanning aims at anticipating (long-term) environmental shifts and analyzing their potential impact [7]. This article concentrates on the latter, hereafter referred to as *environmental scanning.* As strategic issues can emerge within or outside a company, changes in both a company's external and internal environment are relevant.

Thus, *environmental scanning systems* have to specify the sectors to be scanned, monitor the most important indicators of opportunities and threats for the company, cover the IS-based tools to be used, incorporate the findings of such analyses into decision making, and, assign responsibilities for supporting environmental scanning efforts (not covered in this article, but in [20]).

Requirements can be defined as prerequisites, conditions or capabilities needed by users (individuals or systems) to solve a problem or achieve an objective [17]. In computer science, they describe functions and features of IS. The discipline of requirements engineering (RE) aims at increasing the quality of IS development by providing systematic procedures for collecting, structuring, and documenting distinct and collectively exhaustive requirements. Therefore, RE must incorporate the relevant stakeholders and ensure their commitment regarding the final requirements [33].

RE processes consist of three stages [30]. The first phase, requirements identification, focuses on *completeness*. It involves defining the scope of the IS, demarcating the IS from its environment and determining the available sources. Finally, the requirements themselves are collected by analyzing the identified sources using multiple methods (e.g. creativity techniques, literature analysis or empirical methods). The second phase, requirement analysis and specification, focuses on the *distinctiveness* of each requirement. The unstructured requirements are classified first [33]. Overlapping requirements have to be eliminated and the remaining requirements have to be brought into a standard form. Meta languages and models often have an advantage here due to the fact that they are more compact and precise. The focus of the third phase, requirements validation, is twofold and includes *scientific rigor and relevance*. Decisions are made which requirements to use in subsequent design activities (build, realize, and test). Therefore, each requirement is reviewed for scientific rigor. Consensus then has to be reached by stakeholders about the IS requirements and whether they effectively represent their expectations [17].

3 State-of-the-art review

Our prior literature review [24] shows that a rich body of knowledge for environmental scanning exists, but only six out of 85 publications focus on functional requirements and an even minor number of two on non-functional ones (Fig. 1). Additionally, we found three list approaches defined by authors who designed environmental scanning systems themselves.

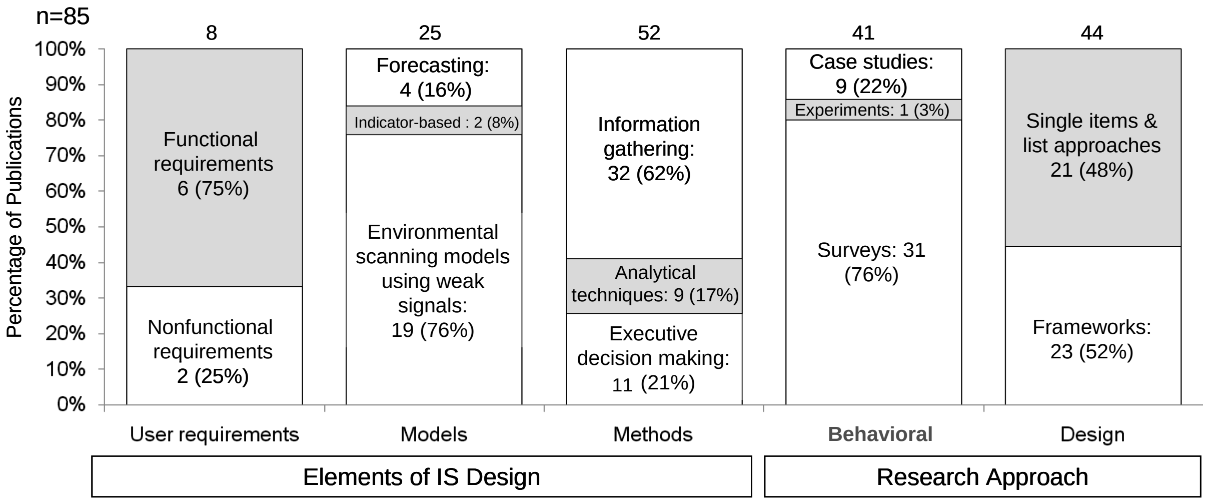


Figure 1: Results of a preliminary literature review [24]

Herein, we differentiated between two different types of list approaches: *Model-free lists of requirements (model-free LoR)* and m*odel-related lists of requirements (model-related LoR).*

We could not identify any example of a more complex structural approach for defining requirements, such as the Technology Acceptance Model (TAM). This may be due to the fact that environmental scanning is often subsumed in executive information systems (EIS) and thus has not been subject to individual research.

3.1 Model-free list of requirements (model-free LoR)

Model-free LoR are characterized by an unsystematic collection of requirements. Frolick et al. [13] use a list approach by mentioning several requirements without any meta structure. A requirement criterion is the integration of external and internal sources that contribute hard and soft data about the environment. Other authors derive their requirements criteria solely from literature [39], best practices, or own experience. These approaches most often do not make use of a meta structure principle or second-level structuring dimensions.

Model-free LoR most often cover few to many variables. The left hand side of Fig. 2 summarizes researched examples of these kinds of requirement lists for environmental scanning systems. Most of them do not specify why certain requirements or dimensions are included. The aim to be relevant for practice dominates scientific rigor.

3.2 Model-related lists of requirements (model-related LoR)

Model-related LoR build or use models to contextualize requirements. They either focus on a few requirements criteria and explain how they have to adjust to dependent variables such as environmental volatility [36, 42] or they define models for direct practical guidance. As an example of the latter Xu et al. [41] provide a model to explain requirements in terms of strength (clarity of the message) and intensity (degree of strategic importance) of a signal.

Model-free lists of requirements

Requirements derived from system design

Narchal et al. (1987)
- Consideration of biases
- Different databases for environments
- Integration of multiple perspectives
- Integration in executive information system (EIS)
- Deliberate, continuous, and systematic scanning
- Scanning culture
- Techniques: scenario technique

Calori (1989)
- Selective and specific search scope
- Scanning frequency
- Historical and structural data forecasts

Frolick et al. (1997)
- Integration of numerous internal and external sources
- Interorganizational integration
- Consideration of cognitive aspects for faster recognition
- Integration of soft and hard data
- Timeliness and accuracy
- Hypermedia navigation
- Integration in executive information system (EIS)
- Techniques: Impact analysis and scenario technique

Requirements derived from literature and own experince

El Sawy (1985)
- Flexibility to changing scope
- Lose coupling to organizational information system
- Classification and manipulation capabilities

Ahituv et al. (1998)
- Scanning frequency
- Formalization
- IT Support

Walters et al. (2003)
- Integration of internal and external information
- Individualized end-user devices
- User-specific information presentation
- Flexibility in terms of addition and modification
- Timeliness and integrity
- Different treatment for scanning areas
- Learning and exploration aids

Day and Shoemaker (2005)
- Adequate search scope
- Past experience integration
- Scanning capabilities benchmark
- Inter- and intraorganizational integration
- Adequate noise filtering

Model-related lists of requirements

Daft and Weick (1984)
Model of organizations as interpretation systems.
Interpretation dependents on:
- Assumptions analyzability of environment
- Firm's intrusiveness

Yasai-Ardekani and Nystrom (1996)
Model for effects of external variables on
- Scanning Frequency
- Top management's responsibility
- Scope

Tan et al. (1998)
Model for effects of external variables on:
- Internet scanning frequency

Xu et al. (2003)
Model for practical guidance.
Scanning depends on:
- Strength – clarity of messages
- Intensity – degree of strategic importance of signal

Figure 2: Examples from literature for model-free and model-related LoR

Model-related LoR focus on putting requirements such as scanning frequency into context and thus concentrate on a few aspects of environmental scanning only. They make use of a superordinate classification. Approaches are summarized in Fig. 2 (right hand side).

3.3 Gap analysis

DSR focuses on accomplishing utility. This section evaluates model-free and model-related LoR based on RE criteria developed in Sec. 2. The results are summarized in Fig. 5 (left two rating columns), using a 5-point rating scale. Model-free LoR cover few to many variables, randomly derived from literature or solely based on the authors' experience or best practice. As the *completeness* of this method is questionable, a weak assessment ("bad") is justified. Model-related LoR put even fewer requirements such as scanning frequency into context and thus provide even less completeness. In terms of *distinctiveness* the model-free LoR lack a method for structuring classification. Thus they are rated "bad." Model-related LoR are much more focused, but provide a superordinate classification ("good"). More interesting are the differences regarding *(scientific) rigor*. The model-free LoR are based on literature research and criteria are selected on the authors' experience. Therefore they are rated "bad." Model-related LoR are based on either empirical evidence or are derived from literature. Since they are focused on few requirements the model derivation is rigor, thus the rating is "good". No easy way exists to judge the *relevance* of the LoR definition approaches. Bearing in mind the fact that truly applicable approaches exist, both receive an average rating ("somewhat").

In summary, both kinds of LoR are applied in practice thanks to their clear information and system antecedents and their ease of use. However, we assessed such approaches negatively in terms of requirement completeness and, more obviously, (scientific) rigor. A promising solution would therefore be to develop a method that incorporates a more rigorous approach without losing relevance. The result should be an applicable list approach to requirements criteria for environmental scanning systems. These criteria have to be derived in a more rigorous and transparent way than the model-free list approaches we researched.

4 Model development

4.1 Principle of economic efficiency

We develop our model following Popper's approach [31] using deduction to systematically define a list of requirements criteria for environmental scanning systems. Focusing on the cost-benefit ratio the principle of economic efficiency is a generally accepted paradigm in business research [32] and IS research [34]. In our case it means that a model design should be oriented what is economically feasible, not what is conceptually or technically possible. Thus it serves as a good starting point for our model [25].

Even though the cost of IS design can be identified to some degree, quantifying the profitability of delivered information is limited. To provide surrogates, we express economic efficiency in a system of basic criteria (Fig. 3). Following the "black box" method from mechanical engineering, these criteria can be differentiated into solution capabilities and resource requirements. *Solution capabilities* cover how IS output supports environmental scanning for managers. The *resource requirements*, in turn, cover the input needed to generate the output.

4.2 First level of specification: design criteria

Following Aguilar's [1] process-oriented view, environmental scanning gathers, interprets, and uses relevant information about events, trends, and relationships in an organization's environment. Thus, we start specifying solution capabilities for environmental scanning systems with *information gathering, interpretation and usage* capabilities. In addition, we suggest *cross-process factors* that contribute to process capabilities and are not subsumed by the previous categories (Fig. 4). Resource requirements can be measured in terms of the *effort* to set up the environmental scanning system.

4.3 Second level of specification: evaluation criteria

The outlined design criteria are rather abstract. With respect to Aguilar [1], environmental scanning systems contribute to a company’s ability to acquire, assimilate and transform new information. Using Zahra and George’s [43] dimensions of a company’s absorptive capacity in mind (acquisition, assimilation, transformation, and exploitation capabilities), brings congruency to Aguilar’s definition (Fig.3). Since these capabilities constitute the company's absorptive capacity, we will examine research based on this theory to specify our requirements criteria. In particular, Volberda et al. [38] and Jansen et al. [18] propose such IS requirements criteria. Fig. 4 illustrates our list of requirements criteria specifying the applicability of environmental scanning systems. Following [25] we go on as follows.

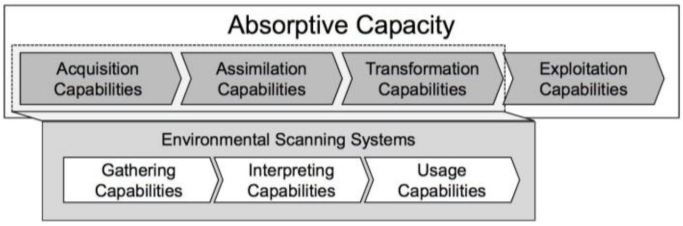
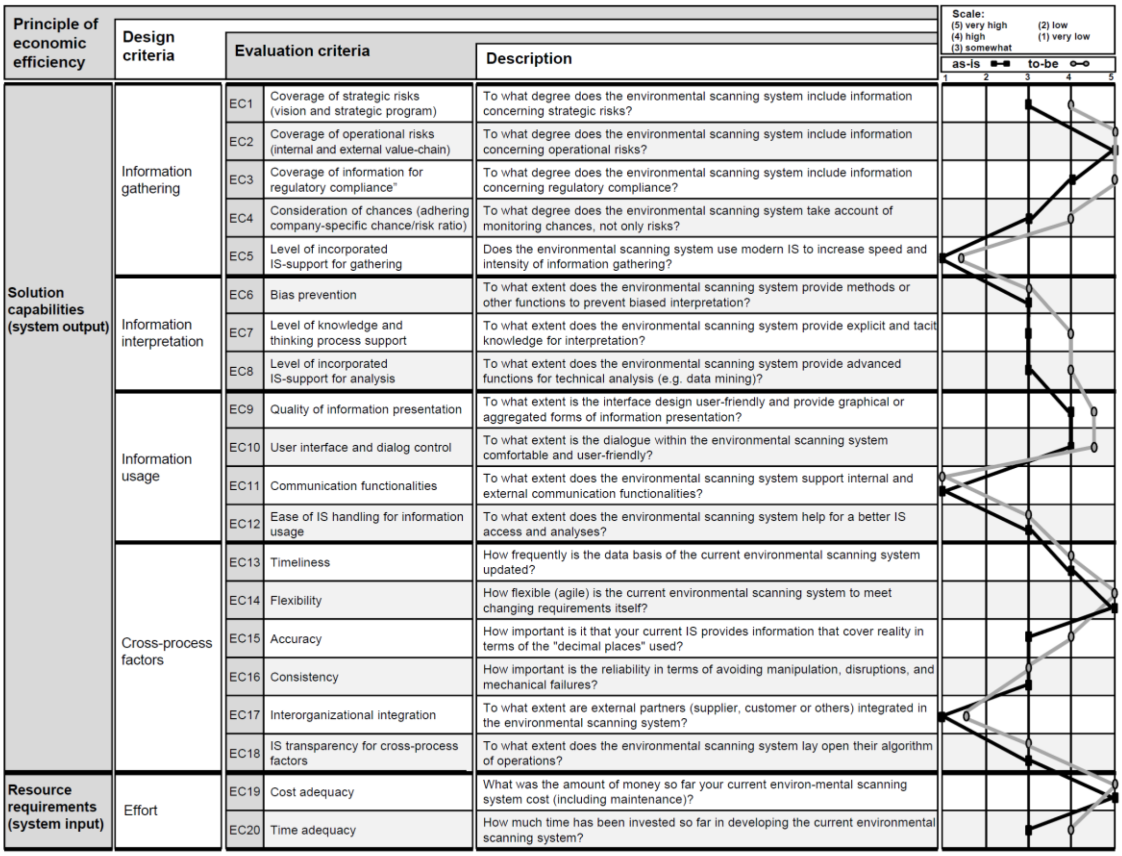


Figure 3: Environmental scanning in the context of absorptive capacity

Information gathering: Zahra and George [43] state three attributes of information gathering: direction; intensity; speed. To the first, we apply the COSO II framework [5]. In doing so, a first objective for environmental scanning systems is to gather information concerning the company's vision and strategic program (mission). Because their direction is high-level and long term, we name the associated risks strategic ones (EC1). Environmental scanning systems also have to incorporate a more short-term perspective. Regarding our definition (Sec. 2) just covering the most important operational risks relevant for management purpose, we focus on those from the internal and external value chain (EC2). Furthermore, environmental scanning systems should focus on gathering information for regulatory compliance (EC3). Information gathering must takes chances in a company-specific ratio into account [37] (EC4). The results are four evaluation criteria concerning the purpose and direction of information gathering for environmental scanning: coverage of three types of risks (EC1-EC3) and chances (EC4). Focusing on the intensity and speed of information gathering, Oh [28] finds evidence that leveraging “modern” IS capabilities (such as data mining, semantic search, and artificial neural networks) or collaboration techniques (such as RSS feeds, customer feedback on social media, professional databases [12]), or business intelligence (BI) with a central data warehouse (DW) significantly enhances a company's information gathering process [23, 28]. We summarize this perspective as the level of incorporated IS-support for gathering (EC5).

Information interpretation: Information interpretation capabilities cover the ability of environmental scanning systems to analyze and transform gathered information [43]. Following the bounded rationality theory information interpretation must take biased human cognition into account [27, 38]. Teece [37] argues that decision makers are biased in several forms. Innovations, for example, appear threatening for most human beings and cause them to disregard potential opportunities. Thus, adopting techniques to overcome these decision biases [37] can result in a competitive advantage. Jansen et al. [18] suggests involving more people in decision making, having subordinates take part in higher-level decisions, and cross-functional interfaces. We summarize this in measuring bias prevention (EC6).

In the theory of bounded rationality, human attention becomes an increasingly scarce resource as the environment becomes more dynamic and complex. That leads to deviations from the rational choice model [21]. Niu et al. [27] propose a "thinking support module" to provide a set of tools for knowledge management, including a case base and a mental model or, more in general, explicit and tacit knowledge. We thus define the level of knowledge and thinking process support as a criterion (EC7).



Principle of economic efficiency	Design criteria	Evaluation criteria		Description
Solution capabilities (system output)	Information gathering	EC1	Coverage of strategic risks (vision and strategic program)	To what degree does the environmental scanning system include information concerning strategic risks?
		EC2	Coverage of operational risks (internal and external value-chain)	To what degree does the environmental scanning system include information concerning operational risks?
		EC3	Coverage of information for regulatory compliance"	To what degree does the environmental scanning system include information concerning regulatory compliance?
		EC4	Consideration of chances (adhering company-specific chance/risk ratio)	To what degree does the environmental scanning system take account of monitoring chances, not only risks?
		EC5	Level of incorporated IS-support for gathering	Does the environmental scanning system use modern IS to increase speed and intensity of information gathering?
	Information interpretation	EC6	Bias prevention	To what extent does the environmental scanning system provide methods or other functions to prevent biased interpretation?
		EC7	Level of knowledge and thinking process support	To what extent does the environmental scanning system provide explicit and tacit knowledge for interpretation?
		EC8	Level of incorporated IS-support for analysis	To what extent does the environmental scanning system provide advanced functions for technical analysis (e.g. data mining)?
	Information usage	EC9	Quality of information presentation	To what extent is the interface design user-friendly and provide graphical or aggregated forms of information presentation?
		EC10	User interface and dialog control	To what extent is the dialogue within the environmental scanning system comfortable and user-friendly?
		EC11	Communication functionalities	To what extent does the environmental scanning system support internal and external communication functionalities?
		EC12	Ease of IS handling for information usage	To what extent does the environmental scanning system help for a better IS access and analyses?
	Cross-process factors	EC13	Timeliness	How frequently is the data basis of the current environmental scanning system updated?
		EC14	Flexibility	How flexible (agile) is the current environmental scanning system to meet changing requirements itself?
		EC15	Accuracy	How important is it that your current IS provides information that cover reality in terms of the "decimal places" used?
		EC16	Consistency	How important is the reliability in terms of avoiding manipulation, disruptions, and mechanical failures?
		EC17	Interorganizational integration	To what extent are external partners (supplier, customer or others) integrated in the environmental scanning system?
		EC18	IS transparency for cross-process factors	To what extent does the environmental scanning system lay open their algorithm of operations?
Resource requirements (system input)	Effort	EC19	Cost adequacy	What was the amount of money so far your current environ-mental scanning system cost (including maintenance)?
		EC20	Time adequacy	How much time has been invested so far in developing the current environmental scanning system?

Figure 4: List of requirements criteria taken from our prior research [25]

From IS support, March and Hevner [23] propose a data warehousing (DW) architecture with integration of external and internal data, as well as BI methods to interpret the information with respect to business tasks. Niu et al. [27] mention online analytical processing (OLAP), SQL reporting, linear programming, and information fusion as methods for data analysis. As a requirements criterion, we include the level of incorporated IS-support (EC8).

Information usage: Environmental scanning systems are worthless if their results are not recognized by managers and, as a consequence, not incorporated into their decision making process [38]. Bearing in mind that managers still tend to be technology-averse and most often have a cognitive working style [19], March and Hevner [23] point out that the IS user interface is a key area determining IS acceptance. Following Warmouth and Yen [40], we evaluate the design of an environmental scanning system's user interface in three dimensions; *quality of information presentation* (EC9), *user interface design and dialog control* (EC10), and advanced functionalities managers can perform themselves. In terms of the latter, we concentrate on *communication functionalities* (EC11). The *ease of IS handling* should help for a better information usage from IS perspective (EC12).

Cross-process factors: Cross-process factors contribute to several of the above-mentioned capabilities. First, the ability to adapt is of utmost importance in changing situations and turbulent environments [10]. Zott [44] defines *timeliness* as an important attribute of such dynamic capabilities (EC13). We add *flexibility* (EC14), the ability of the IS to adapt to changing information needs, data sources, and ways to present information. Although Sutcliffe and Weber [35] state that how managers interpret their environment is more important than how accurately they know it, managers will not use information if it is questionable in terms of its formal aspects or content. This leads us to propose the requirements criteria of accuracy (EC15) and consistency (EC16).

Interorganizational factors such as a company's social embeddedness, increase its absorptive capacity [28, 38]. A strong business network across different companies enables information sharing and collection to increase system sensitivity to upcoming external events [28]. Gulati [14] proposes that companies can be highly alert if they "create and utilize wide-ranging information networks." Given the importance of such networking activities, supporting companies' *interorganizational integration* is another requirements criterion for applicable environmental scanning systems (EC17). Automatic validation checks are an example for IS support in the cross-process factors. Thus, *IS transparency* should contribute to the cross-process factors (EC18).

Effort: Our final requirements criteria consider the effort needed to design, implement, and set up environmental scanning systems. Zott [44] states that "even if dynamic capabilities are equifinal across firms, robust performance may arise […] if the costs and timing of dynamic capability deployment differ […]." *Cost adequacy* (EC19) and *time adequacy* (EC20) are defined as the last requirements criteria.

5 Demonstrate

We are in progress of applying our model at five large international companies. A first demonstration was the adoption of our model on hand at a large, international company (sales: USD 56 bn; employees: 174,000). The following information was collected in an interview with the manager of the corporate controlling at the headquarter. He was asked to rate their environmental scanning system in terms of our evaluation criteria on a scale from "1" (very low) to "5" (very high). The resulting evaluation is visualized in Fig. 4 (right-hand side).

Information gathering: The environmental scanning system is widespread throughout the entire company and includes many different departments. The IS the interviewee is working with, has an operational focus. Other departments are more concerned on strategic aspects and the regulatory compliance. But the different IS have not been integrated yet. The IS itself does not support weak signals at the moment. Especially for strategic risks this is a feasible improvement (EC1-3). Besides risks, the IS covers opportunity identification, but is still focusing on risk identification (EC4). Data is collected manually. Thus advanced information gathering functionalities are not implemented, but would speed up the gathering process significantly (EC5).

Information interpretation: The current IS is based on MS Excel. It offers basic analytical functionalities such as trend calculation. Currently no benefits are seen in introducing more sophisticated analytical functionalities (EC6). Bias prevention as well as knowledge and thinking support is provided by double review interpretation and a mind map for possible outcomes of early indicator movements. In future increasing bias prevention techniques and a case base for knowledge integration is considered (EC7, EC8).

Information usage: The IS fulfills the purpose of a reporting instrument. Based on interactive "pdf" documents it enhances an interactive information retrieval and easy-to-use IS navigation. In turn communication functionalities are not integrated (EC11). Based on traffic light coding and qualitative aggregation the IS provides several levels of analysis (EC9, EC10). Overall ease of IS handling for information usage is considered adequate (EC12).

Cross-process factors: Environmental scanning is done on a monthly basis and data is updated accordingly. Considering the areas to be scanned and the vision of the company there is no desire for higher scanning frequency (EC13). Bearing in mind easy-to-handle characteristics the IS is considered to be very flexible. Adjustments to changing requirements can be performed quickly and further indicators can be introduced easily (EC14). The accuracy and consistency of information provided is considered adequate (EC15, EC16). Currently there is no need for interorganizational integration (EC17) or any improvement in overall IS transparency (EC18).

Effort: The IS is easy to handle and based on understandable, most often distinct processes. Thus the cost adequacy is very high (EC19). Since the IS currently requires a lot of manual work the time adequacy could be increased by automating some routines (EC20).

6 Model evaluation

Comparing the findings with the comments to our LoR (Sec. 3) and using the criteria derived in Sec. 2, our proposed model has the following advantages to be discussed.

The principle of economic efficiency is widely *accepted*. As a reliable, frequently applied design paradigm, it provides a generally accepted starting point for IS requirement analysis. From a conceptual perspective, deriving evaluation criteria from a theory is scientifically *rigorous.* As we also included cross-functional IS aspects, our approach should lead to a good level of *completeness*. Considering *relevance,* it is hard to evaluate our approach because until now just five implementations exist. In general our approach should lead to the same level as both other LoR approaches (Fig. 5). Nevertheless our list approach is *not exhaustive*.

Relating environmental scanning to the absorptive capacity theory is a new approach. It can be criticized that using theory for evaluating applicability is a contradiction. But research about supporting factors of these theoretical constructs is logically based and has been subject to other empirical investigations. Comparing this approach with those using own experience and random literature our model is more *systematic* and offers *less subjectiveness.*

○ Very bad ◔ Bad ◑ Somewhat ◕ Good ● Very good

		Evaluation criteria	Model-free LoR (Sec 3.1)	Model-related LoR (Sec. 3.2)	Approach on hand
Requirements engineering	Requirement identification	Completeness	◔	○	◕
	Requirement analysis and specification	Distinctiveness	◔	◕	◕
	Requirement validation	(Scientific) rigor	◔	◕	◕
		Relevance	◑	◑	◑

Figure 5: Evaluating the approach on hand in comparison to other list approaches

7 Outlook and future research

The objective of this article was to develop a list of requirements criteria contributing to a more applicable environmental scanning system design without sacrificing scientific rigor. Based on the principle of economic efficiency and using findings from the adsorptive capacity theory, we derived 20 criteria. They can be applied for both, evaluate existing environmental scanning systems and develop a new, more applicable IS-generation than those designed by previous research. A first demonstration showed the applicability of our requirements list on hand. Looking ahead, we are going to apply it in case studies with four additional large, international companies resulting in "as-is/to-be" profiles of environmental scanning systems to identify best practices and current design gaps.

The evaluation schema itself incorporates several opportunities for empirical research as it provides a first step to measure the applicability of environmental scanning systems and identify opportunities for further improvements. Applicable environmental scanning systems should help executives to perform a more proactive corporate management, foreseeing emerging threats and opportunities in an increasing volatile environment. Overall, the method used to develop our criteria should necessarily be applicable to other IS domains as well and thus contribute to improve requirement analysis in IS design research in general.

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